

CRD-5FF0912P

SiC MOSFET High-Frequency Evaluation Board for 7L D2PAK



User's Manual

CPWR-AN17, Rev -

CREE Power Applications

This document is prepared as a user reference guide to install and operate CREE evaluation hardware.

All parts of this document are provided in English, and the Cautions are provided in English, Mandarin, and Japanese. If the end user of this board is not fluent in any of these languages, it is your responsibility to ensure that they understand the terms and conditions described in this document, including without limitation the hazards of and safe operating conditions for this board.

本文件中的所有内容均以英文书写，“注意”部分的内容以英文、中文和日语书写。若本板子的终端用户不熟悉上述任何一种语言，则您应当确保该终端客户能够理解本文件中的条款与条件，包括且不限于本板子的危险以及安全操作条件。

当書類のすべての内容は英語で書きます。「注意点」の内容は英語、中国語、また日本語で書きます。当ボードの端末使用者は上記の言語が一つでもわからないなら、当端末使用者は当書類の条約と条件が理解できるのを確保すべきです。そして、当ボードの危険や安全に使用する条件を含み、また限りません。



Note: This Cree-designed evaluation hardware for Cree components is meant to be used as an evaluation tool in a lab setting and to be handled and operated by highly qualified technicians or engineers. The hardware is not designed to meet any particular safety standards and the tool is not a production qualified assembly.

CAUTION

PLEASE CAREFULLY REVIEW THE FOLLOWING PAGE, AS IT CONTAINS IMPORTANT INFORMATION REGARDING THE HAZARDS AND SAFE OPERATING REQUIREMENTS RELATED TO THE HANDLING AND USE OF THIS BOARD.

警告

请认真阅读以下内容，因为其中包含了处理和使用本板子有关的危险和安全操作要求方面的重要信息。

警告

ボードの使用、危険の対応、そして安全に操作する要求などの大切な情報を含むので、以下の内容をよく読んでください。

**CAUTION**

DO NOT TOUCH THE BOARD WHEN IT IS ENERGIZED AND ALLOW THE BULK CAPACITORS TO COMPLETELY DISCHARGE PRIOR TO HANDLING THE BOARD. THERE CAN BE VERY HIGH VOLTAGES PRESENT ON THIS EVALUATION BOARD WHEN CONNECTED TO AN ELECTRICAL SOURCE, AND SOME COMPONENTS ON THIS BOARD CAN REACH TEMPERATURES ABOVE 50° CELSIUS. FURTHER, THESE CONDITIONS WILL CONTINUE FOR A SHORT TIME AFTER THE ELECTRICAL SOURCE IS DISCONNECTED UNTIL THE BULK CAPACITORS ARE FULLY DISCHARGED.

Please ensure that appropriate safety procedures are followed when operating this board, as any of the following can occur if you handle or use this board without following proper safety precautions:

- **Death**
- **Serious injury**
- **Electrocution**
- **Electrical shock**
- **Electrical burns**
- **Severe heat burns**

You must read this document in its entirety before operating this board. It is not necessary for you to touch the board while it is energized. All test and measurement probes or attachments must be attached before the board is energized. You must never leave this board unattended or handle it when energized, and you must always ensure that all bulk capacitors have completely discharged prior to handling the board. Do not change the devices to be tested until the board is disconnected from the electrical source and the bulk capacitors have fully discharged.

警告

请勿在通电情况下接触板子，在处理板子前应使大容量电容器完全释放电力。接通电源后，该评估板上可能存在非常高的电压，板子上一些组件的温度可能超过50摄氏度。此外，移除电源后，上述情况可能会短暂持续，直至大容量电容器完全释放电量。

操作板子时应确保遵守正确的安全规程，否则可能会出现下列危险：

- 死亡
- 严重伤害
- 触电
- 电击
- 电灼伤
- 严重的热烧伤

请在操作本板子前完整阅读本文件。通电时不必接触板子。在为板子通电前必须连接所有测试与测量探针或附件。通电时，禁止使板子处于无人看护状态，或操作板子。必须确保在操作板子前，大容量电容器释放了所有电量。只有在切断板子电源，且大容量电容器完全放电后，才可更换待测试器件。

警告

通电している時、ボードに接触するのは禁止です。ボードを処分する前に、大容量のコンデンサーで電力を完全に釈放すべきです。通电してから、ボードにひどく高い電圧が存在している可能性があります。ボードのモジュールの温度は50度以上になるかもしれません。また、電源を切った後、上記の状況がしばらく持続する可能性がありますので、大容量のコンデンサーで電力を完全に釈放するまで待ってください。

ボードを操作するとき、正確な安全ルールを守るのを確保すべきです。さもないと、以下の危険がある可能性があります：

- 死亡
- 重症
- 感電
- 電撃
- 電気の火傷
- 厳しい火傷

当ボードを操作する前に、完全に当書類をよく読んでください。通电している時にボードに接触する必要がありません。通电する前に必ずすべての試験用のプローブあるいはアクセサリをつないでください。通电している時に無人監視やボードを操作するのは禁止です。ボードを操作する前に、大容量のコンデンサーで電力を完全に釈放するのを必ず確保してください。ボードの電源を切った後、また大容量のコンデンサーで電力を完全に釈放した後、試験設備を取り換えることができます。

1. Introduction

The purpose of this evaluation board is to demonstrate the high-switching performance of Cree 3rd Generation Silicon Carbide (SiC) Metal Oxide Semiconductor Field-Effect Transistors (MOSFETs) in a 7L D2PAK package. The new surface-mount device (SMD), specifically designed for high voltage MOSFETs, has a small footprint with a wide creepage distance of 7mm between drain and source. The new package also includes a separate driver source connection, which reduces gate ringing and provides clean gate signals. This evaluation board (Figure 1) comes configured as a basic half bridge circuit with two C3M0120090J SiC MOSFETs installed. The board can easily be configured into common power conversion topologies such as synchronous boost, synchronous buck, Inverter, and other topologies. This board was designed to make it easy for the user to:

- Evaluate SiC MOSFET switching performance in a 7L D2PAK package to characterize E_{ON} and E_{OFF} losses.
- Evaluate thermal performance. The integrated heatsink is predrilled with a blind hole on the backside for thermocouples so the heatsink surface temperature can be accurately estimated.
- Serve as a PC board layout example for driving Gen 3 SiC MOSFETs in the newly developed 7L D2PAK package.
- Easily evaluate the effects of different R_g values, Miller clamps, uni-polar versus bipolar gate drive, fault detection circuit, various thermal interface materials, and cooling methods.

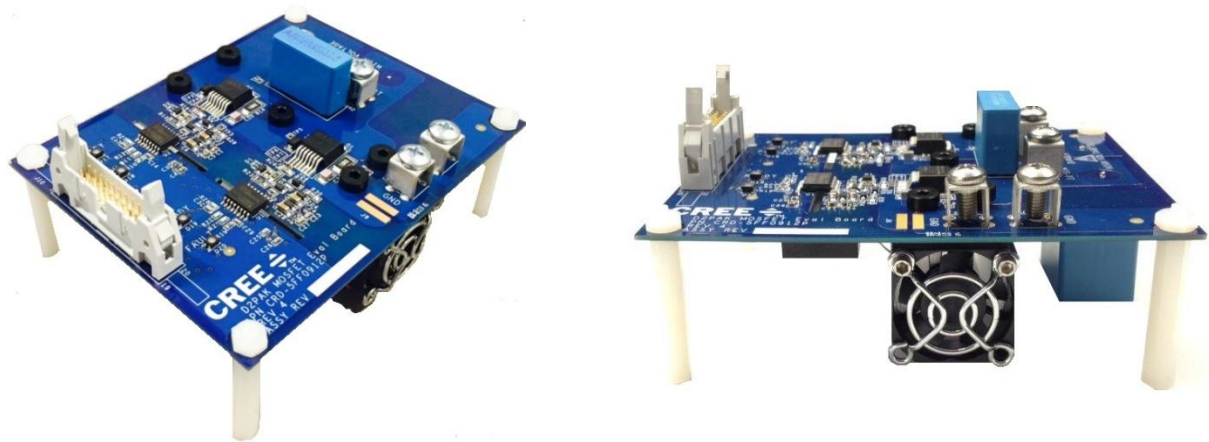


Figure 1. Evaluation Board (top and side view)

2. Features

The evaluation board's physical dimensions are 127mm x 98mm x 58mm. The board comes preassembled with an isolated heatsink, cooling fan, and 2 SiC MOSFETS. The heatsink is attached to the board with five nonconductive screws (RENY hexagon socket low head cap bolt M5 6mm).

A block diagram of the evaluation board is shown in Figure 2. Besides the two Cree 900V, 120mΩ (C3M0120090) SiC MOSFETs (Q1 and Q2), there are two onboard isolated gate driver circuits to drive both Q1 and Q2. There are four power connectors (CON1, CON2, CON3, and CON4) for connecting to the +DC link, -DC link, and midpoint. There is a 20 pin signal/supply voltage ribbon cable connector (J10) onboard which carries the logic power, status signals, fault signals, and gate drive control signals.

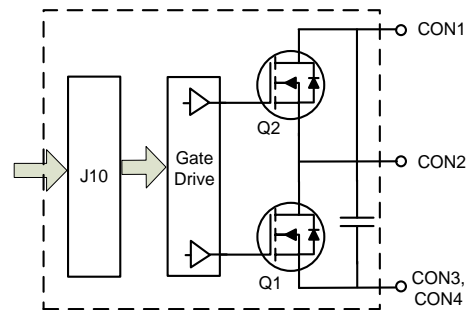


Figure 2. Block Diagram

Each gate drive circuit consists of a 2A isolated gate driver chip and a generous 2W isolated DC/DC converter that can comfortably switch the SiC MOSFETs at up to 3MHz. The driver chip provides 1200V of isolation between the low voltage control side and the high voltage drive side. The DC/DC converters are sourced with +12V on their inputs. Through a series of jumpers, JM1-JM6 (Figure 4), the gate drivers can each be configured as a low cost uni-polar (+15V/0V) gate drive or as a high performance bi-polar gate drive (+15V/-3V). The DC/DC converters provide a maximum of 5.2kV of isolation for 60 seconds. The complete board assembly will withstand a 1.5kVAC.rms Hi-pot test for 60 seconds.

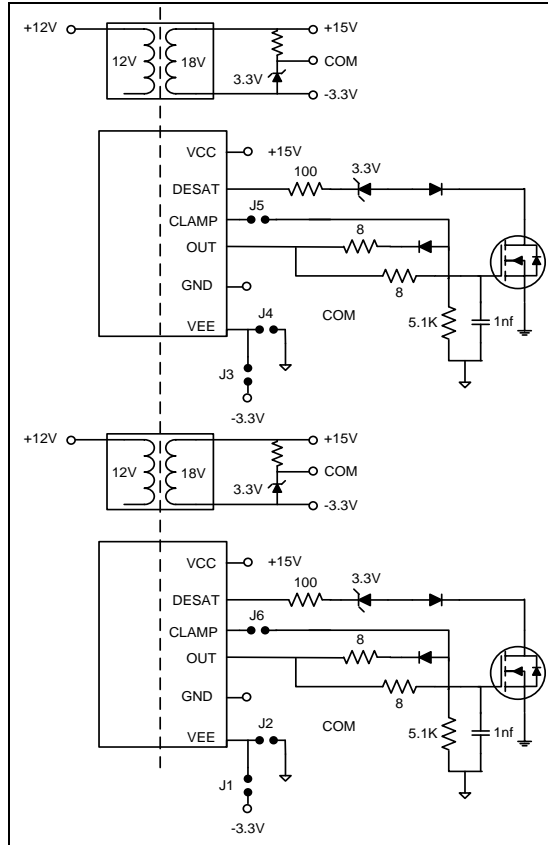


Figure 3. Gate Drive Circuit

Table 1 shows how the jumpers should be configured depending on the desired gate drive output levels.

Gate Drive Output		
	+15V/-3V	+15V/0V
JM1, JM3	SHORT	OPEN
JM2, JM4	OPEN	SHORT
JM5, JM6	OPEN	SHORT

Table 1. Jumper Table

There is a short circuit protection function for each gate drive circuit by means of Vds voltage monitoring. The drain of each MOSFET is monitored (Figure 4). When either of the MOSFETs is in the ON state, and the drain voltage exceeds approximately 5.7V, the gate driver reverts to the OFF state and the fault signal for the channel is toggled.

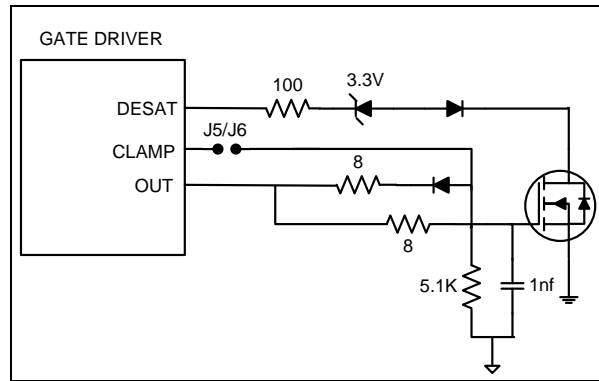


Figure 4. Gate Drive shown with Miller Clamp and short circuit protection.

In a half bridge configuration, turning on one device tends to induce a voltage on the opposing device gate node. If this voltage exceeds the threshold voltage it is possible to get an unintended shoot through event in certain devices. A negative gate bias (Bi-polar drive) is one common way to mitigate this issue. When using a uni-polar drive sometimes it is common to use a Miller clamp to ensure that the gate voltage of the opposing device is clamped below the threshold voltage. To activate the Miller clamp, a jumper (JM5=upper channel, JM6=lower channel) needs to be shorted. The Miller clamp should only be enabled when the gate driver is configured for +15V/0V output voltage.

Although we provide this feature on the board for the user to evaluate the effects of the Miller clamp, it is not necessary to have a Miller clamp. The SiC MOSFET channel is not fully turned ON when the gate voltage exceeds the device threshold voltage. For Cree SiC MOSFETs, the gate voltage would have to exceed 9V to have a significant shoot through event.

2.1 Cooling



CAUTION

IT IS NOT NECESSARY FOR YOU TO TOUCH THE BOARD WHILE IT IS ENERGIZED. WHEN DEVICES ARE BEING ATTACHED FOR TESTING, THE BOARD MUST BE DISCONNECTED FROM THE ELECTRICAL SOURCE AND ALL BULK CAPACITORS MUST BE FULLY DISCHARGED.

SOME COMPONENTS ON THE BOARD REACH TEMPERATURES ABOVE 50° CELSIUS. THESE

CONDITIONS WILL CONTINUE AFTER THE ELECTRICAL SOURCE IS DISCONNECTED UNTIL THE BULK CAPACITORS ARE FULLY DISCHARGED. DO NOT TOUCH THE BOARD WHEN IT IS ENERGIZED AND ALLOW THE BULK CAPACITORS TO COMPLETELY DISCHARGE PRIOR TO HANDLING THE BOARD.

PLEASE ENSURE THAT APPROPRIATE SAFETY PROCEDURES ARE FOLLOWED WHEN OPERATING THIS BOARD AS SERIOUS INJURY, INCLUDING DEATH BY ELECTROCUTION OR SERIOUS INJURY BY ELECTRICAL SHOCK OR ELECTRICAL BURNS, CAN OCCUR IF YOU DO NOT FOLLOW PROPER SAFETY PRECAUTIONS.

警告

通电时不必接触板子。连接器件进行测试时，必须切断板子电源，且大容量电容器必须释放完所有电量。

板子上一些组件的温度可能超过50摄氏度。移除电源后，上述情况可能会短暂持续，直至大容量电容器完全释放电量。通电时禁止触摸板子，应在大容量电容器完全释放电量后，再操作板子。

请确保在操作板子时已经遵守了正确的安全规程，否则可能会造成严重伤害，包括触电死亡、电击伤害、或电灼伤。

警告

通电している時にボードに接触する必要がありません。設備をつないで試験する時、必ずボードの電源を切ってください。また、大容量のコンデンサーで電力を完全に釈放してください。

ボードのモジュールの温度は50度以上になるかもしれません。電源を切った後、上記の状況がしばらく持続する可能性がありますので、大容量のコンデンサーで電力を完全に釈放するまで待ってください。通电している時にボードに接触するのは禁止です。大容量のコンデンサーで電力をまだ完全に釈放していない時、ボードを操作しないでください。

ボードを操作している時、正確な安全ルールを守っているのを確保してください。さもないと、感電、電撃、厳しい火傷などの死傷が出る可能性があります。

The evaluation board has several integrated features designed for effective thermal management. The top and bottom side of the board uses heavy 8oz. copper to help dissipate heat better. It also has a 3mm diameter solid copper inlay directly under the SiC MOSEFTs (Q1 and Q2) to effectively transfer the heat to the bottom side of the board. The board is mechanically attached via 5 nonconductive screws to an extruded aluminum heatsink with an integrated 30mm fan. Since the

heatsink is common to both MOSFETs it needs to be isolated from the bottom copper on the board yet be thermally conductive. This is achieved via a high performance 0.01 inch thermal interface material, Sil-Pad 2000 manufactured by Bergquist (Mfg. P/N SP2000-0.010-00-1212). A thermal stack up of the assembly is shown below in Figure 5.

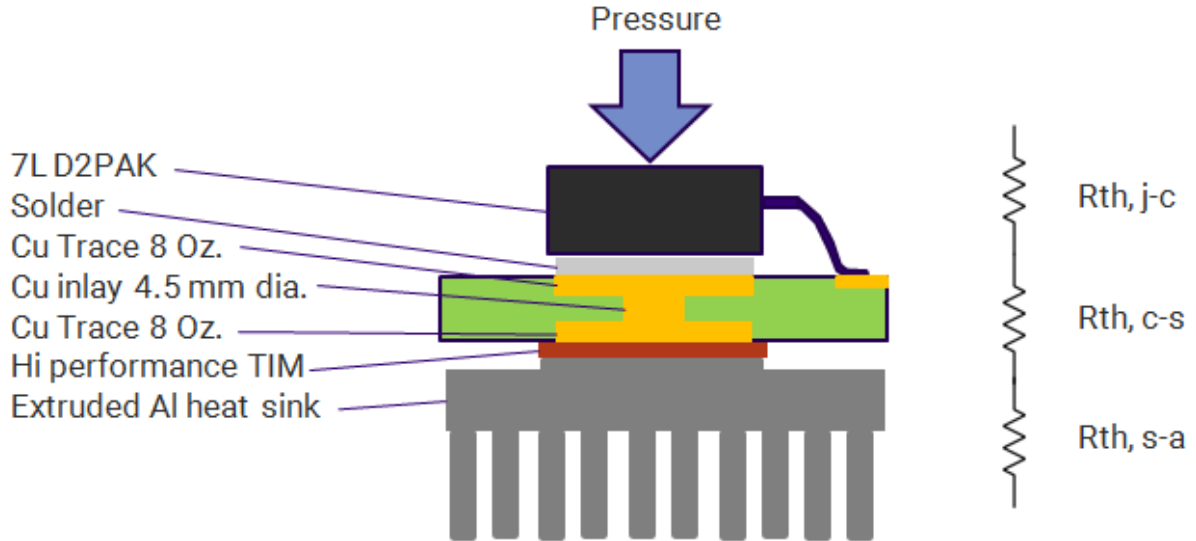


Figure 5. Thermal management and assembly stack up.

The measured values for the thermal resistance from the device junction (C3M0120090J) to the case ($R_{th,j-c}$), from the device case to the surface of the heatsink ($R_{th,c-s}$), and from the heatsink to ambient with the fan turned ON with a 12VDC source ($R_{th,s-a}$), is listed in Table 2 below.

Parameter	Value	Note
$R_{th,j-c}$ ($^{\circ}\text{C}/\text{W}$), max	1.5	From data sheet
$R_{th,c-s}$ ($^{\circ}\text{C}/\text{W}$)	0.56	
$R_{th,s-a}$ ($^{\circ}\text{C}/\text{W}$)	2.46	Integrated fan ON

Table 2. Measured thermal resistance values

3. Example Topologies

The half bridge circuit topology was chosen for its flexibility, as it forms the common switch node in many common topologies. Two example configurations are listed below, with the

components shown outside the dotted box to be provided by the user. There are other topologies that can be configured, like non-synchronous buck or boost topologies, with minor modifications to the board. In addition, the user could quickly prototype an H-bridge or 6-pak based topology with the addition of multiple evaluation boards.

A. Synchronous Buck Converter

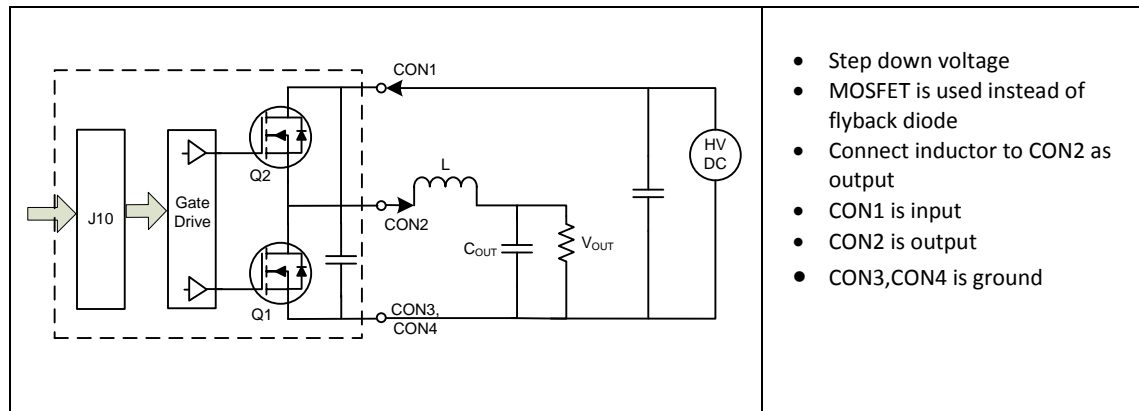


Figure 6a. Evaluation Board setup as Synchronous Buck Converter

B. Synchronous Boost Converter

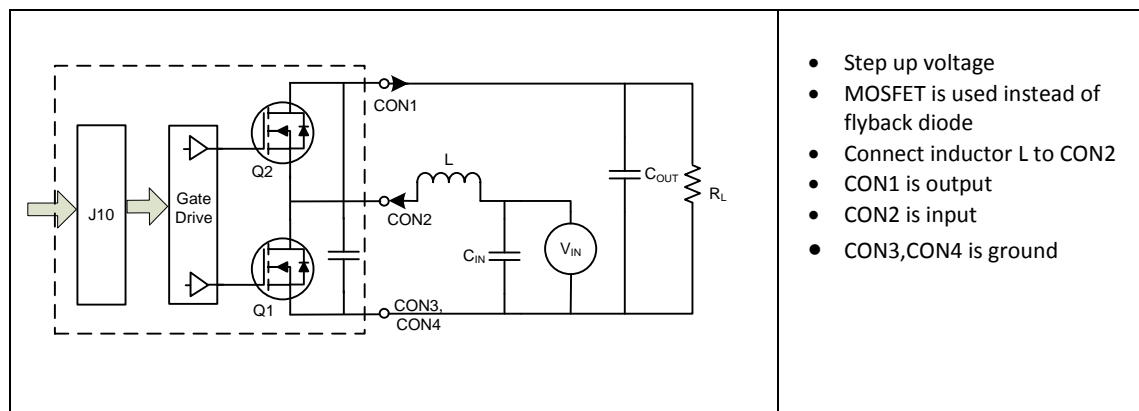


Figure 6b. Evaluation Board setup as Synchronous Boost Converter

4. Connectors



CAUTION
*****HIGH VOLTAGE RISK*****

THERE CAN BE VERY HIGH VOLTAGES PRESENT ON THIS BOARD WHEN CONNECTED TO AN ELECTRICAL SOURCE, AND SOME COMPONENTS ON THIS BOARD CAN REACH TEMPERATURES ABOVE 50° CELSIUS. FURTHER, THESE CONDITIONS WILL CONTINUE AFTER THE ELECTRICAL SOURCE IS DISCONNECTED UNTIL THE BULK CAPACITORS ARE FULLY DISCHARGED. DO NOT TOUCH THE BOARD WHEN IT IS ENERGIZED AND ALLOW THE BULK CAPACITORS TO COMPLETELY DISCHARGE PRIOR TO HANDLING THE BOARD.

The connectors on the board have very high voltage levels present when the board is connected to an electrical source, and thereafter until the bulk capacitors are fully discharged. Please ensure that appropriate safety procedures are followed when working with these connectors as serious injury, including death by electrocution or serious injury by electrical shock or electrical burns, can occur if you do not follow proper safety precautions. When devices are being attached for testing, the board must be disconnected from the electrical source and all bulk capacitors must be fully discharged. After use the board should immediately be disconnected from the electrical source. After disconnection any stored up charge in the bulk capacitors will continue to charge the connectors. Therefore, you must always ensure that all bulk capacitors have completely discharged prior to handling the board.

警告
*****高压危险*****

接通电源后，该评估板上可能存在非常高的电压，板子上一些组件的温度可能超过50摄氏度。此外，移除电源后，上述情况可能会短暂持续，直至大容量电容器完全释放电量。通电时禁止触摸板子，应在大容量电容器完全释放电量后，再触摸板子。

板子上的连接器在充电时以及充电后都具有非常高的电压，直至大容量电容器完全释放电量。请确保在操作板子时已经遵守了正确的安全流程，否则可能会造成严重伤害，包括触电死亡、电击伤害或电灼伤。连接器件进行测试时，必须切断板子电源，且大容量电容器必须释放了所有电量。使用后应立即切断板子电源。切断电源后，大容量电容器中存储的电量会继续输入至连接器中。因此，必须始终在操作板子前，确保大容量电容器已完全释放电量。

警告

高圧危険

通電してから、ボードにひどく高い電圧が存在している可能性があります。ボードのモジュールの温度は50度以上になるかもしれません。また、電源を切った後、上記の状況がしばらく持続する可能性がありますので、大容量のコンデンサーで電力を完全に釈放するまで待ってください。通電している時にボードに接触するのは禁止です。大容量のコンデンサーで電力をまだ完全に釈放していない時、ボードに接触しないでください。

ボードのコネクターは充電中また充電した後、ひどく高い電圧が存在しているので、大容量のコンデンサーで電力を完全に釈放するまで待ってください。ボードを操作している時、正確な安全ルールを守っているのを確保してください。さもなければ、感電、電撃、厳しい火傷などの死傷が出る可能性があります。設備をつないで試験する時、必ずボードの電源を切ってください。また、大容量のコンデンサーで電力を完全に釈放してください。使用後、すぐにボードの電源を切ってください。電源を切った後、大容量のコンデンサーに貯蓄している電量はコネクターに持続的に入るので、ボードを操作する前に、必ず大容量のコンデンサーの電力を完全に釈放するのを確保してください。

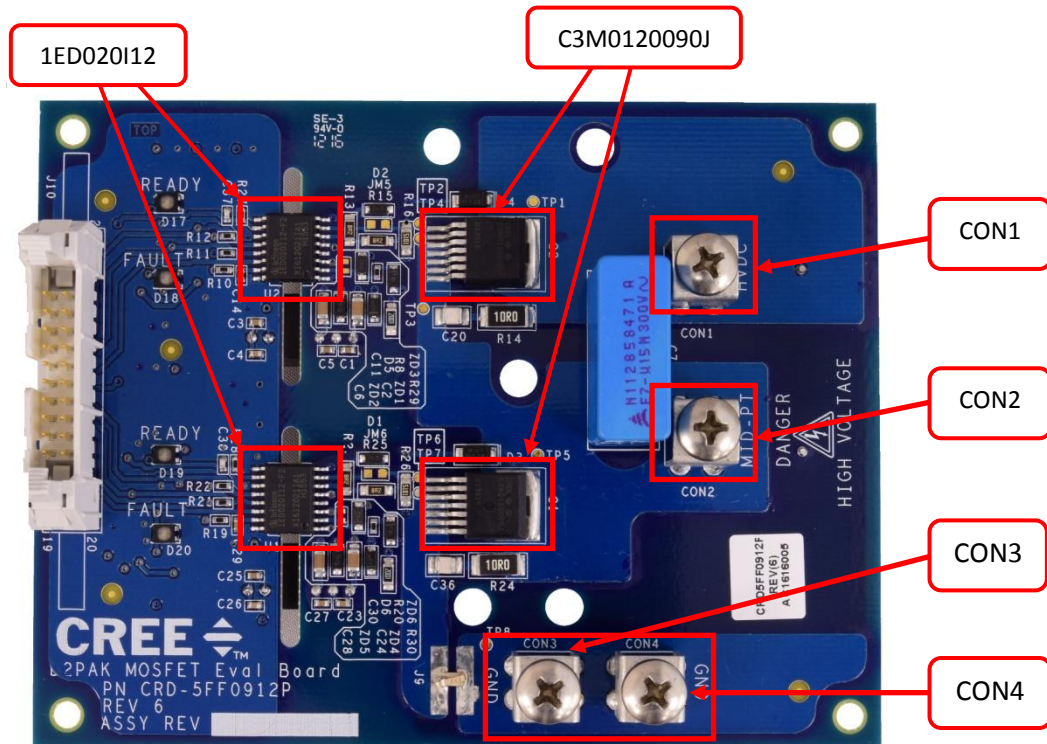


Figure 7. Board Top View with Main Features labeled

4.1 Test Pad Locations

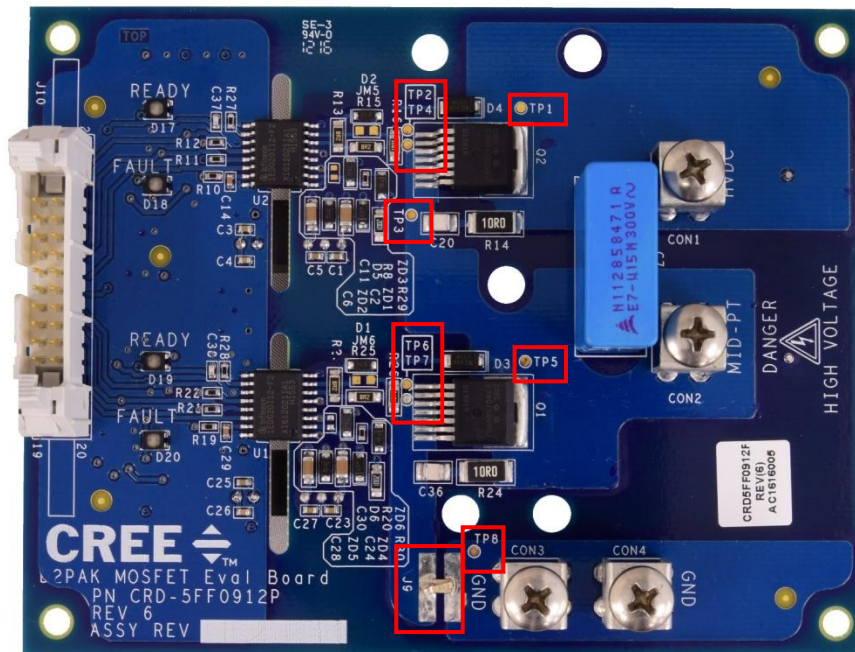


Figure 8. Board Top View with test points labeled

The test pads highlighted in Figure 8 allow various types of pin headers and solderable posts to be soldered on all the major nodes so oscilloscope probes can be attached. Figure 9 shows a pair of pin headers soldered onto test points 6&7 allowing an oscilloscope probe to monitor V_{DS} for the lower MOSFET (Figure 10).

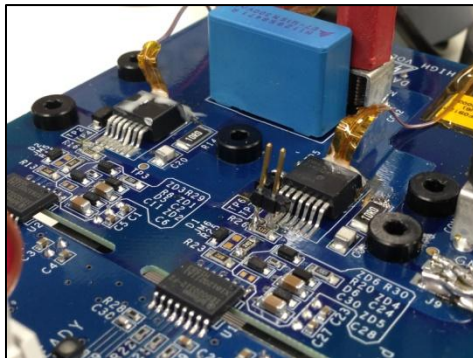


Figure 9. Pin headers on test points

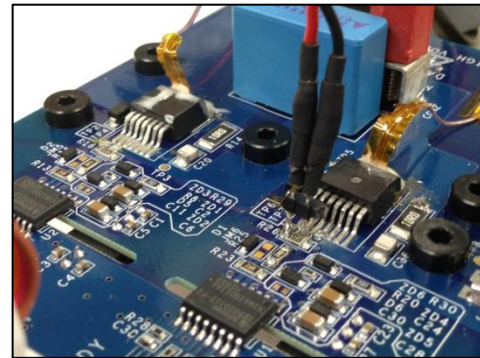


Figure 10. Scope probe on pin headers

Terminals CON1, CON2, CON3 and CON4 are the power terminals, and their definitions vary based on topology. The terminals are vertical through-hole connectors with a 10-32 threaded hole and a screw provided. The terminals can accommodate a cable with a

ring or spade style connector with 1/4" width and a 10-32 screw. The control signals are all contained on connector J10. The definition of J10 for each pin is shown in Table 3.

1	COMMON	2	PWR IN (+12V)
3		4	COMMON
5		6	HIGH SIDE POWER GOOD, 5V=POWER GOOD, 0V=POWER BAD
7		8	HIGH SIDE FAULT, 5V=NO FAULT, 0V=DESAT FAULT
9		10	HIGH SIDE RESET, PULL DOWN TO COMMON TO RESET FAULT
11		12	HIGH SIDE PWM INPUT, 5V=SWITCH ON, 0V=SWITCH OFF
13		14	LOW SIDE POWER GOOD, 5V=POWER GOOD, 0V=POWER BAD
15		16	LOW SIDE FAULT, 5V=NO FAULT, 0V=DESAT FAULT
17		18	LOW SIDE RESET, PULL DOWN TO COMMON TO RESET FAULT
19		20	LOW SIDE PWM INPUT, 5V=SWITCH ON, 0V=SWITCH OFF

Table 3. Pin definitions for connector J10

The heatsink fan is powered by 12VDC. The 12V fan can be powered from the same 12V power supply that is powering the evaluation board.

5. Switching loss measurement

This board is ideal for making double pulsed clamped inductive load switching measurements. Figure 11 shows how the board should be connected to make the switching measurements.

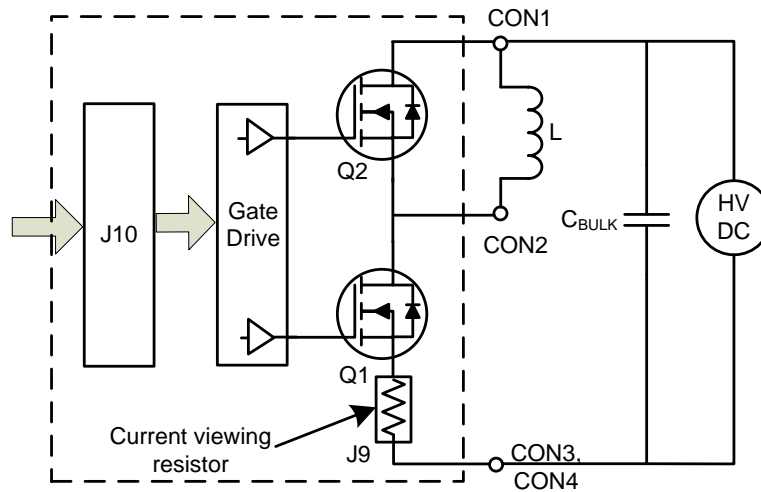


Figure 11. Clamped Inductive Switching Measurement Circuit

A precision current viewing resistor will be needed so that the current through Q1 can be measured. There are provisions (J9) on the board for installing a through-hole current viewing resistor. The board comes with a jumper in place. This jumper must be removed when adding a current viewing resistor. T&M Research makes a viewing resistor (part #SDN-414-01) (Figure 12) that can be used with this board. The resistor has a resistance of 10milliohms and therefore works with most

oscilloscopes with the probe attenuation set to x100. If the user selects a different resistor, the user should ensure that the resistor has minimal insertion inductance.



Figure 12. SDN-414-01 (sold separately)

Due to the fast switching speeds associated with Cree SiC MOSFETs, the following steps must be followed closely to yield the most accurate results possible:

- Scope probes measuring V_{DS} and V_{GS} must have minimal loop area between the signal and ground.
- The oscilloscope probes measuring V_{DS} and I_{DS} must be properly deskewed.
- Bulk capacitance may need to be added to the board to minimize DC link voltage sag during two-pulse measurements. The amount will vary based on desired current level and pulse width.

Figure 14 shows a two-pulse setup. Figure 15 shows the waveforms measured with this two-pulse setup.

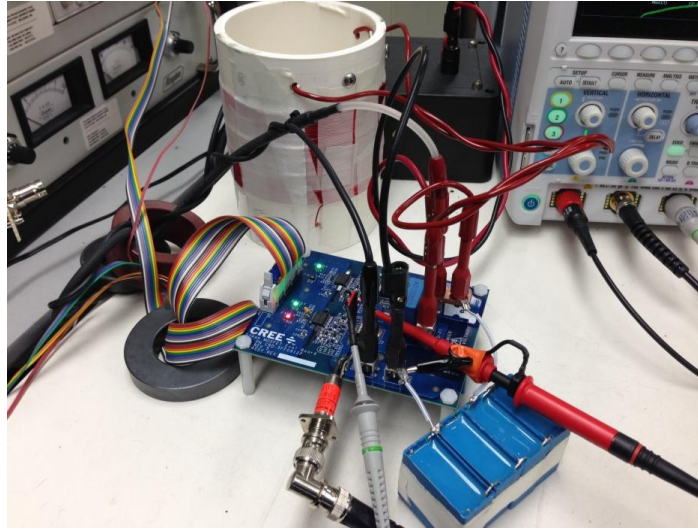
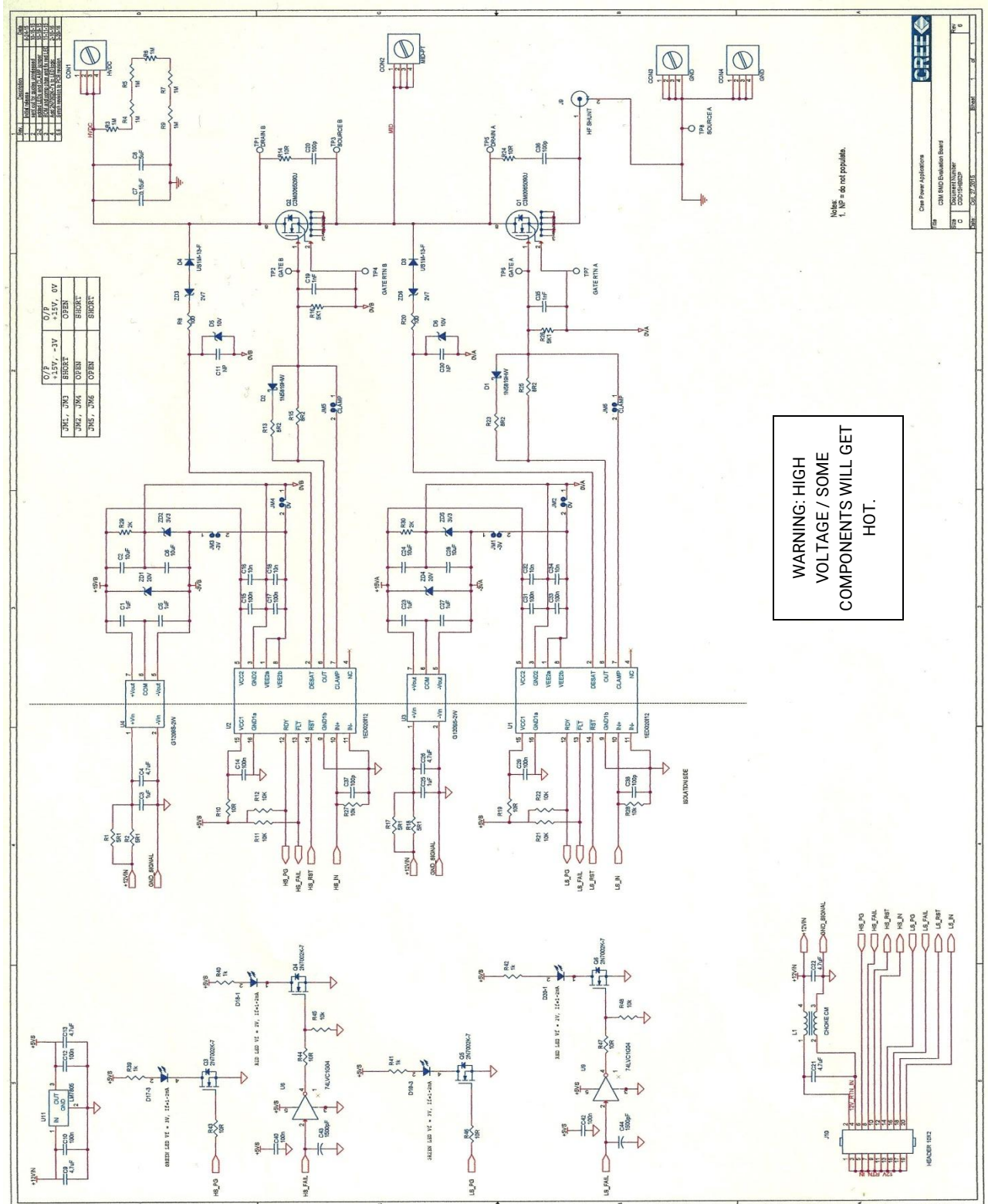


Figure 14. Probes connected to evaluation board



Figure 15. Waveforms measured with evaluation board

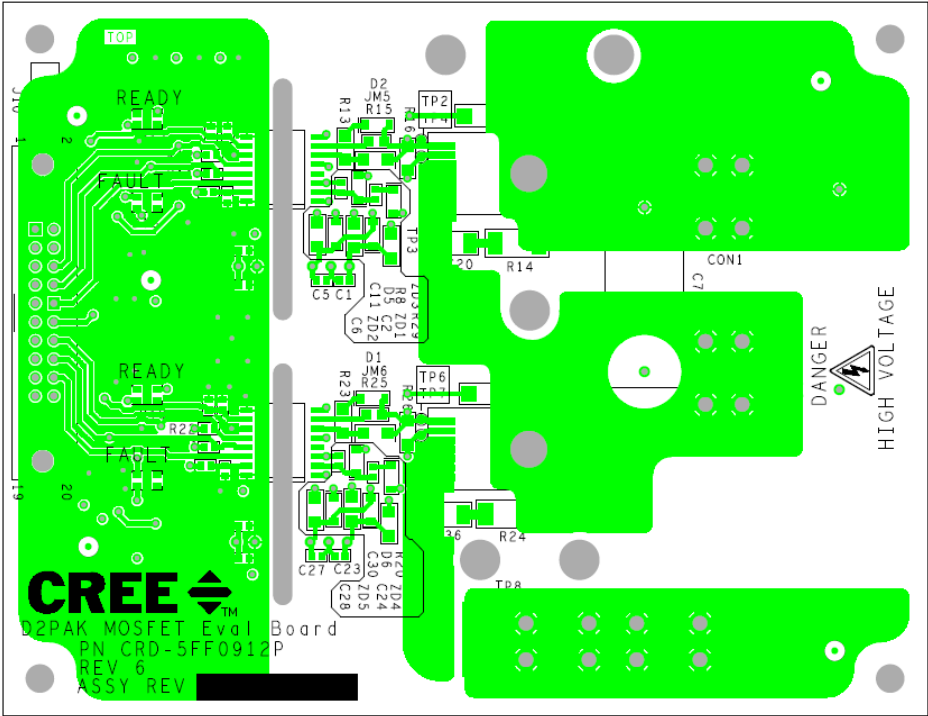
6. Appendix



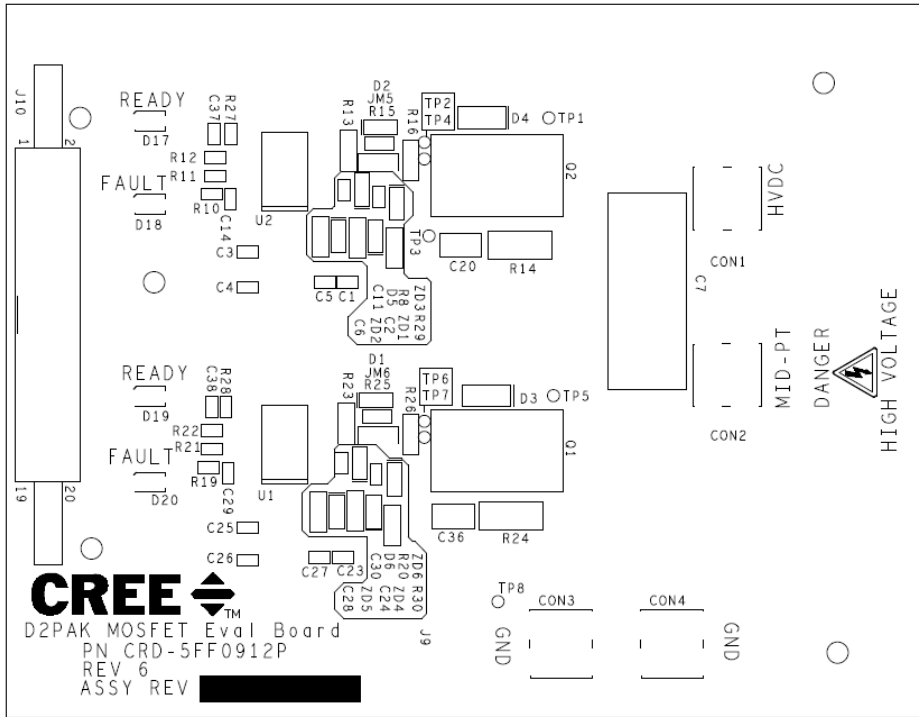


7. PCB Layout Drawings

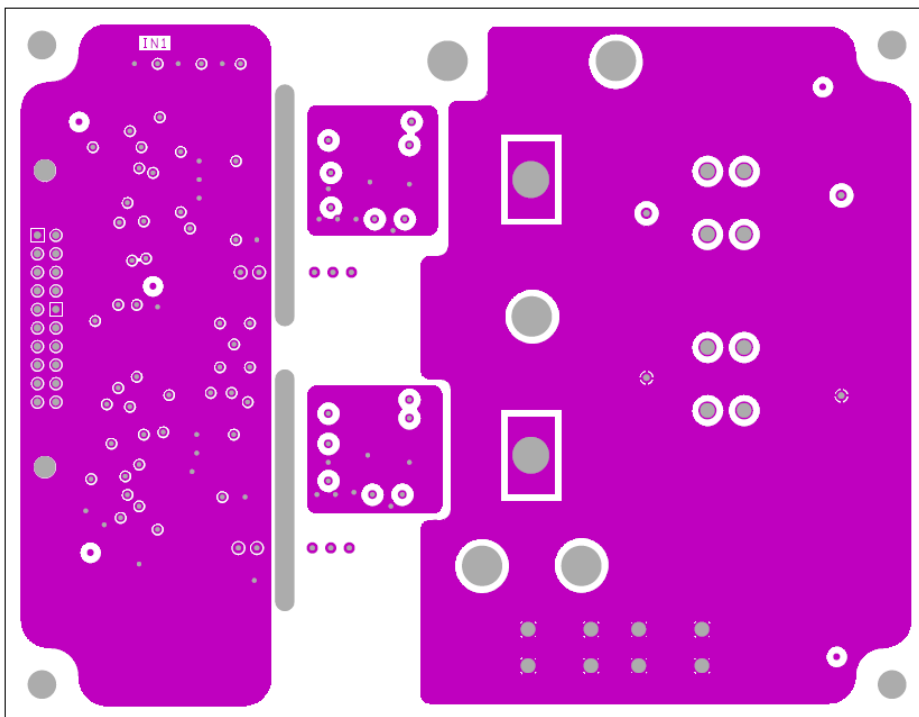
Top Traces



Top Silkscreen

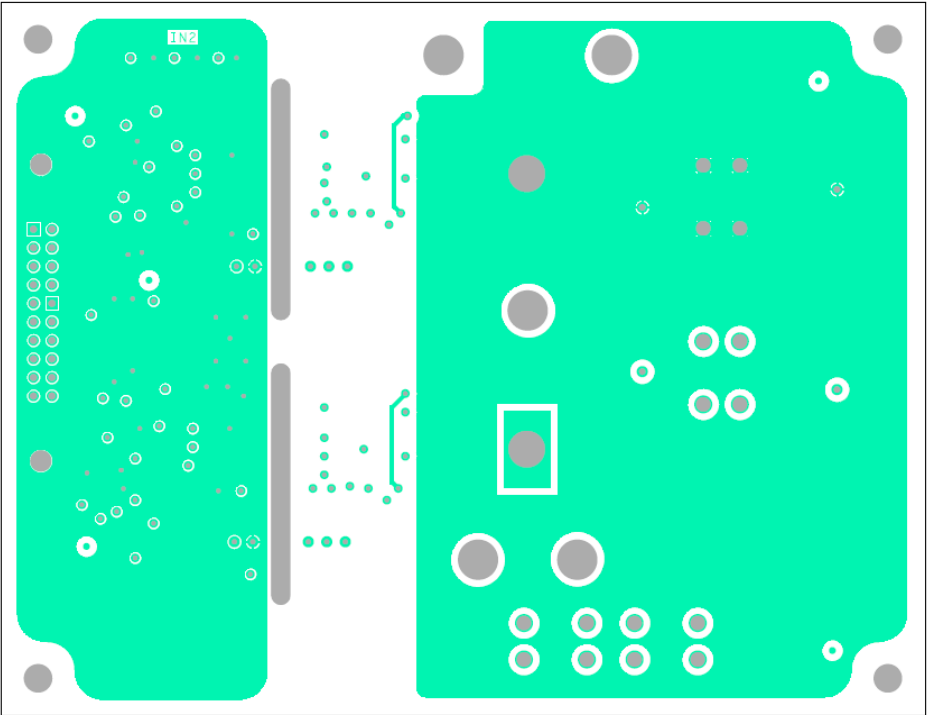


Inner Layer 1 Traces

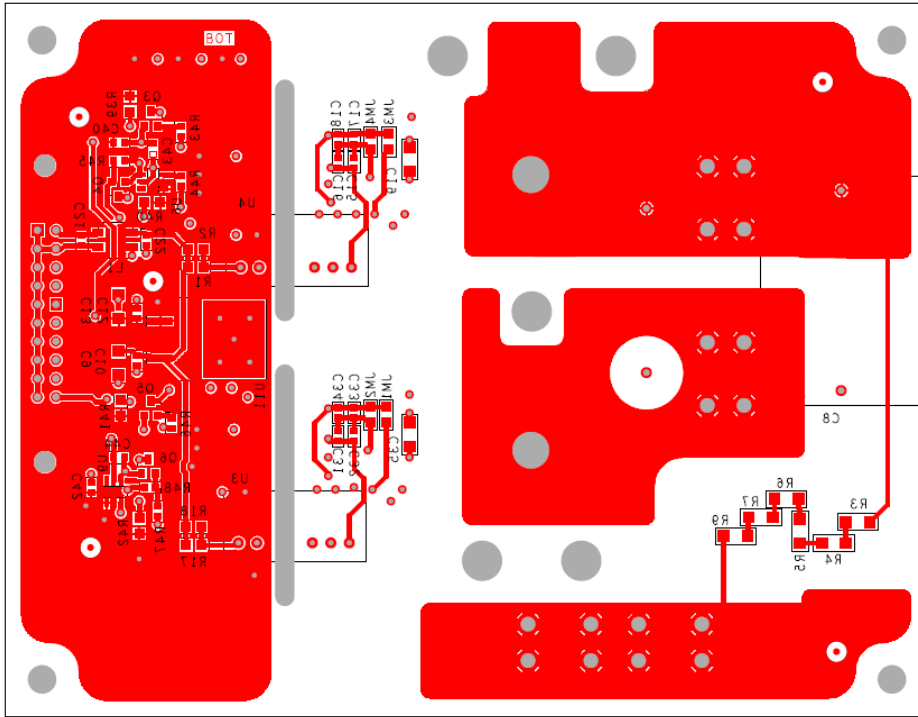




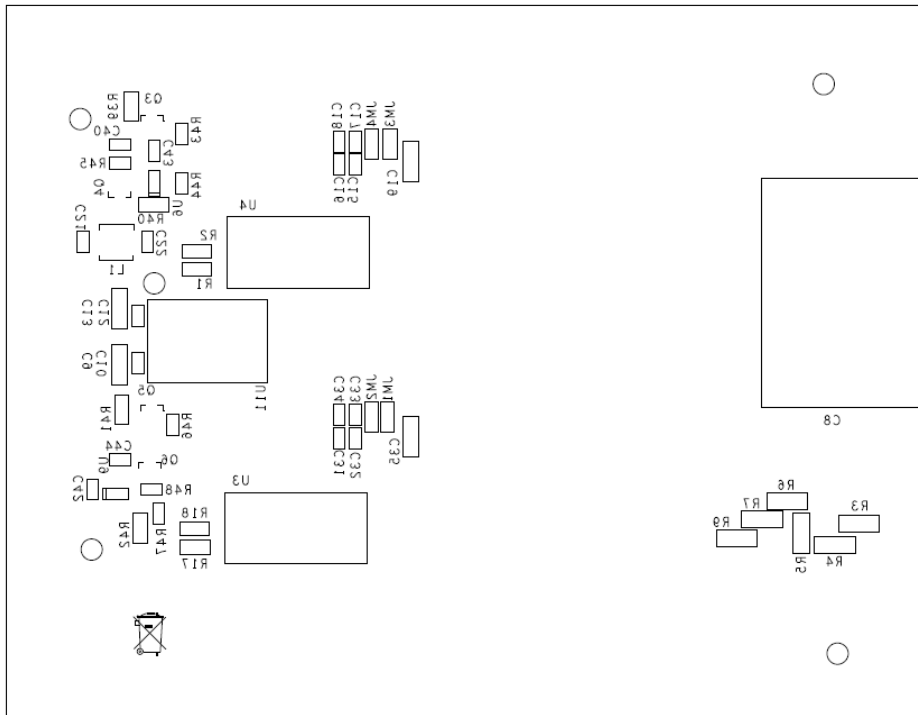
Inner Layer 2 Traces



Bottom Traces



Bottom Silkscreen





8. Bill of Materials

Item	Qty Per	Reference Designator	Description	Manufacturer Name	Manufacturer's P/N
1	4	CON1,CON2,CON3,C ON4	TERM PC SNAPIN VRT 10-32 W/SCREW	KEystone	8174
2	6	C1,C3,C5,C23,C25,C27	CAP CER 1uf 50V 10% X7R 0603	Open	UMK107AB7105KA-T
3	4	C2,C6,C24,C28	CAP CER 10UF 35V X7R 1206	Open	GMK316AB7106KL-TR
4	4	C4,C21,C22,C26	CAP CER 4.7UF 25V X5R 0603	Open	CL10A475KA8NQNC
5	1	C7	CAP FILM 0.15UF 20% 1.5KVDC RAD	Epcos	B32023A3154M
6	1	C8	CAP FILM 5UF 10% 1.3KVDC RADIAL	Epcos	B32774D1505K
7	2	C9,C13	CAP CER 4.7uf 50V 10% X7R 1206	Open	UMK316AB7475KL-T
8	10	C10,C12,C14,C15,C17,C29,C31,C33,C40,C42	CAP CER 0.1uf 50V 10% X7R 0603	Open	CL10B104KB8SFNC
9	4	C16,C18,C32,C34	CAP CER 10,000pf 50V 10% X7R 0603	Open	C1608X7R2A103K080AA
10	2	C19,C35	CAP CER 1000PF 50V X7R 1206	Open	CL31B102KBCNNNC
11	2	C20,C36	100pf, X7R, 10%, 2kV ceramic capacitor	Open	C1210C101KGRACU
12	2	C37,C38	CAP CER 100pf 50V 10% X7R 0603	Open	CL10B101KB8NNNC
13	2	C43,C44	CAP CER 1500PF 50V X7R 0603	Open	CL10B152KB8NNNC
14	2	D1,D2	DIODE SCHOTTKY 40V 1A SOD123	Diodes Inc.	1N5819HW-7-F
15	2	D3,D4	DIODE GEN PURP 1KV 1A SMA	Diodes Inc.	US1M-13-F
16	2	D5,D6	DIODE ZENER 10V 500MW SOD123	Diodes Inc.	MMSZ5240B-7-F
17	2	D17,D19,D18,D20	LED RGB DIFFUSED 4PLCC SMD	Cree	CLVBA-FKA-CAEDH8BBB7A363
18	2	JM1,JM3	RES 0 OHM jumper 1/8W 1% 0805 SMD	Open	ERJ-6GEY0R00V
19	1	J9	PC TEST POINT COMPACT SMT	Keystone	5016
20	1	J10	20Pin 2X10 vertical header	FCI	71918-120LF
21	1	L1	common mode choke	TDK	ACM4520-142-2P-T000
22	2	Q1,Q2	MOSFET, D2PAK-7	Cree	C3M0120090J
23	4	Q3,Q4,Q5,Q6	MOSFET N-CH 60V 300MA SOT23-3	Diodes Inc.	2N7002K-7
24	4	R1,R2,R17,R18	RES SMD 5.1 OHM 5% 1/8W 0805	Open	RC0805JR-075R1L
25	6	R3,R4,R5,R6,R7,R9	RES SMD 1M OHM 1% 1/4W 1206	Open	ERJ-8ENF1004V

26	2	R8,R20	RES SMD 100 OHM 1% 1/8W 0603	Open	MCT06030C1000FP500
27	2	R10,R19	RES 10 OHM 1/16W 1% 0603 SMD	Open	ERJ-3EKF10R0V
28	8	R11,R12,R21,R22,R27,R28,R45,R48	RES SMD 10K OHM 1% 1/10W 0603	Open	ERJ-3EKF1002V
29	4	R13,R15,R23,R25	RES SMD 8.2 OHM 5% 1/3W 1206	Open	ESR18EZPJ8R2
30	2	R14,R24	RES SMD 10 OHM 1% 2W 2512	Open	CRM2512-FX-10R0ELF
31	2	R16,R26	RES SMD 5.1K OHM 1% 1/4W 1206	Open	ERJ-8ENF5101V
32	2	R29,R30	RES SMD 2K OHM 1% 1/4W 1206	Open	ERJ-8ENF2001V
33	4	R39,R40,R41,R42	RES SMD 1K OHM 1% 1/8W 0805	Open	ERJ-6ENF1001V
34	4	R43,R44,R46,R47	RES 10 OHM 1/16W 1% 0603 SMD	Open	ERJ-3EKF10R0V
35	2	U1,U2	IC IGBT DVR 1200V 2A DSO16	Infineon	1ED020I12F2XUMA1
36	2	U3,U4	DC/DC CONV 5.2KV ISO SIP7 TH 2W	Murata	MEJ2D1209SC
37	2	U6,U9	IC SINGLE INVERTER-GATE SOT-23-5	TI	SN74LVC1G04DBVR
38	1	U11	5V, 1A regulator	On Semiconductor	MC7805CD2TR4G
39	2	ZD1,ZD4	DIODE ZENER 20V 500MW SOD123	On Semiconductor	MMSZ20T1G
40	2	ZD2,ZD5	DIODE ZENER 3.3V 500MW SOD123	Diodes Inc.	MMSZ5226B
41	2	ZD3,ZD6	DIODE ZENER 2.7V 500MW SOD123	On Semiconductor	MMSZ2V7T1G
42	1	(mechanical)	Heat Sink (Aavid Thermalloy custom)	Cree	111115-01
43	5	(mechanical)	RENY Hexagon socket low head cap bolt M5 6mm	SolidSpot	RENYLC506
44	1	(mechanical)	FAN AXIAL 30X10MM 12VDC WIRE	Sunon	MC30101V1-000U-A99
45	1	(mechanical)	FINGER GUARD 30MM METAL	Qualtek	8346
46	2	(mechanical)	Zinc-Plated Steel Pan Head Phillips Machine Screw, Internal Washer, 4-40 Thread, 5/8" Length	McMaster-Carr	90403A112
47	4	(mechanical)	Nylon 6/6 Male-Female Threaded Hex Standoff, 1/4" Hex, 1-1/2" Length, 6-32 Screw Size	McMaster-Carr	92745A348
48	4	(mechanical)	Nylon 6/6 Hex Nut, 6-32 Thread Size, 5/16" Wide, 1/8" High	McMaster-Carr	94812A300
49	2	(mechanical)	Thermal Interface, 1"x1"	Bergquist	SP2000-0.010-00-1212



IMPORTANT NOTES

Purposes and Use

Cree, Inc. (on behalf of itself and its affiliates, “Cree”) reserves the right in its sole discretion to make corrections, enhancements, improvements, or other changes to the board or to discontinue the board.

THE BOARD DESCRIBED IS AN ENGINEERING TOOL INTENDED SOLELY FOR LABORATORY USE BY HIGHLY QUALIFIED AND EXPERIENCED ELECTRICAL ENGINEERS TO EVALUATE THE PERFORMANCE OF CREE POWER SWITCHING DEVICES. THE BOARD SHOULD NOT BE USED AS ALL OR PART OF A FINISHED END PRODUCT. THIS BOARD IS NOT SUITABLE FOR SALE TO OR USE BY CONSUMERS AND CAN BE HIGHLY DANGEROUS IF NOT USED PROPERLY. THIS BOARD IS NOT DESIGNED OR INTENDED TO BE INCORPORATED INTO ANY OTHER PRODUCT FOR RESALE. THE USER SHOULD CAREFULLY REVIEW THE DOCUMENT TO WHICH THESE NOTIFICATIONS ARE ATTACHED AND OTHER WRITTEN USER DOCUMENTATION THAT MAY BE PROVIDED BY CREE (TOGETHER, THE “DOCUMENTATION”) PRIOR TO USE. USE OF THIS BOARD IS AT THE USER’S SOLE RISK.

Operation of Board

It is important to operate the board within Cree’s recommended specifications and environmental considerations as described in the Documentation. Exceeding specified ratings (such as input and output voltage, current, power, or environmental ranges) may cause property damage. If you have questions about these ratings, please contact Cree at sic_power@cree.com prior to connecting interface electronics (including input power and intended loads). Any loads applied outside of a specified output range may result in adverse consequences, including unintended or inaccurate evaluations or possible permanent damage to the board or its interfaced electronics. Please consult the Documentation prior to connecting any load to the board. If you have any questions about load specifications for the board, please contact Cree at sic_power@cree.com for assistance.

Users should ensure that appropriate safety procedures are followed when working with the board as serious injury, including death by electrocution or serious injury by electrical shock or electrical burns can occur if you do not follow proper safety precautions. It is not necessary in proper operation for the user to touch the board while it is energized. When devices are being



attached to the board for testing, the board must be disconnected from the electrical source and any bulk capacitors must be fully discharged. When the board is connected to an electrical source and for a short time thereafter until board components are fully discharged, some board components will be electrically charged and/or have temperatures greater than 50° Celsius. These components may include bulk capacitors, connectors, linear regulators, switching transistors, heatsinks, resistors and SiC diodes that can be identified using a board schematic. Users should contact Cree at sic_powr@cree.com for assistance if a board schematic is not included in the Documentation or if users have questions about a board's components. When operating the board, users should be aware that these components will be hot and could electrocute or electrically shock the user. As with all electronic evaluation tools, only qualified personnel knowledgeable in handling electronic performance evaluation, measurement, and diagnostic tools should use the board.

User Responsibility for Safe Handling and Compliance with Laws

Users should read the Documentation and, specifically, the various hazard descriptions and warnings contained in the Documentation, prior to handling the board. The Documentation contains important safety information about voltages and temperatures.

Users assume all responsibility and liability for the proper and safe handling of the board. Users are responsible for complying with all safety laws, rules, and regulations related to the use of the board. Users are responsible for (1) establishing protections and safeguards to ensure that a user's use of the board will not result in any property damage, injury, or death, even if the board should fail to perform as described, intended, or expected, and (2) ensuring the safety of any activities to be conducted by the user or the user's employees, affiliates, contractors, representatives, agents, or designees in the use of the board. User questions regarding the safe usage of the board should be directed to Cree at sic_power@cree.com.

In addition, users are responsible for:

- compliance with all international, national, state, and local laws, rules, and regulations that apply to the handling or use of the board by a user or the user's employees, affiliates, contractors, representatives, agents, or designees.
- taking necessary measures, at the user's expense, to correct radio interference in the event that operation of the board causes interference with radio communications. The board may generate, use, and/or radiate radio frequency energy, but it has not been tested for compliance within the limits of computing devices pursuant to Federal Communications



Commission or Industry Canada rules, which are designed to provide protection against radio frequency interference.

- compliance with applicable regulatory or safety compliance or certification standards that may normally be associated with other products, such as those established by EU Directive 2011/65/EU of the European Parliament and of the Council on 8 June 2011 about the Restriction of Use of Hazardous Substances (or the RoHS 2 Directive) and EU Directive 2002/96/EC on Waste Electrical and Electronic Equipment (or WEEE). The board is not a finished end product and therefore may not meet such standards. Users are also responsible for properly disposing of a board's components and materials.

No Warranty

THE BOARD IS PROVIDED "AS IS" WITHOUT WARRANTY OF ANY KIND, INCLUDING BUT NOT LIMITED TO ANY WARRANTY OF NON-INFRINGEMENT, WHETHER EXPRESS OR IMPLIED. THERE IS NO REPRESENTATION THAT OPERATION OF THIS BOARD WILL BE UNINTERRUPTED OR ERROR FREE.

Limitation of Liability

IN NO EVENT SHALL CREE BE LIABLE FOR ANY DAMAGES OF ANY KIND ARISING FROM USE OF THE BOARD. CREE'S AGGREGATE LIABILITY IN DAMAGES OR OTHERWISE SHALL IN NO EVENT EXCEED THE AMOUNT, IF ANY, RECEIVED BY CREE IN EXCHANGE FOR THE BOARD. IN NO EVENT SHALL CREE BE LIABLE FOR INCIDENTAL, CONSEQUENTIAL, OR SPECIAL LOSS OR DAMAGES OF ANY KIND, HOWEVER CAUSED, OR ANY PUNITIVE, EXEMPLARY, OR OTHER DAMAGES. NO ACTION, REGARDLESS OF FORM, ARISING OUT OF OR IN ANY WAY CONNECTED WITH ANY BOARD FURNISHED BY CREE MAY BE BROUGHT AGAINST CREE MORE THAN ONE (1) YEAR AFTER THE CAUSE OF ACTION ACCRUED.

Indemnification

The board is not a standard consumer or commercial product. As a result, any indemnification obligations imposed upon Cree by contract with respect to product safety, product liability, or intellectual property infringement do not apply to the board.